

## Ceramics for Turbomachinery Systems

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Marshall and a team of industry experts, under a NASA Aerospace Industry Technology Program cooperative agreement, are developing a manufacturing process for silicon nitride ceramic components. Under this agreement, a team of engineers from AlliedSignal Aerospace Equipment Systems, AlliedSignal Ceramic Components, AlliedSignal Technology Team, Allison Engine Company, MSFC, and Lewis Research Center are working to develop and demonstrate ceramic turbine-wheel technology suitable for air turbine starters, with potential applications for other turbomachinery such as turbopumps, turbochargers, and turbogenerators.

Ultimately, the efforts of this team should lead to the commercialization of ceramic turbine-wheel technology. To accomplish this, the team will develop and demonstrate low-cost, high-yield ceramic manufacturing processes. In order to provide the turbomachinery technology outlined in this agreement, the team must develop gelcasting as a low-cost, high-yield ceramic-forming process, develop brazing as a high-load capacity, low-cost ceramic-to-metal attachment, and demonstrate ceramic turbine wheels in an air turbine starter.

The development of this manufacturing process for turbine wheels will build on newly developing uses for gelcasting, while the new ceramic-to-metal attachment will employ current brazing techniques. Once the manufacturing process has been defined,

the turbine wheels will be produced and tested in an Aerospace Equipment Systems production air turbine starter. These tests will focus on the entire spectrum of operating conditions, as well as duration testing. Next, Allison Engine Company will provide field service tests of the air turbine starter with the ceramic wheels. Tinker Air Force Base has also expressed intent to test starters with ceramic wheels on service aircraft.

In order to design the turbine wheels and components necessary to adapt the turbine wheels to the existing air turbine starter, the team will take advantage of the developments from a previous ceramic turbine research program. Although the turbines for this project are axial in design, the resulting technology will also benefit ceramic forming processes for radial turbines.

In addition to developing the gelcasting technique, Ceramic Components will conduct material characterization tests and produce the turbine wheels. The ceramic-to-turbine brazing technique, being developed by the AlliedSignal Technology Team, will be transferred to Ceramic Components and Aerospace Equipment Systems.

Since the 1980's, AlliedSignal Aerospace Equipment Systems and Ceramic Components have worked together, designing, developing, fabricating, and testing ceramic turbines for air turbine starters. Their efforts have provided a rich pool of resources and insight into the primary factors necessary to successfully design air turbine starters.

A working model of the turbine wheel has already been released to Ceramic Components to fabricate the tooling that will be used for process development, and Ceramic Components has already begun to optimize the process. Development to date has focused on the slip development, binder burnout and densification phases of the gelcasting process. Ceramic Components is also reviewing past research programs of mold designs under the Aerospace Industry Technology Program. In a concurrent effort, the design and procurement of development

molds is underway. The company has planned a program to cast existing turbine-wheel designs to evaluate their dimensional control and repeatability.

The AlliedSignal Technology Team has tested brazed shaft attachments using a variety of sizes, materials, and geometric configurations. Using a simple geometry consisting of a silicon nitride stub shaft brazed onto a steel-stub shaft, full torque strength has been achieved. This team has also improved process repeatability by refining brazed materials and techniques. Short-range plans for the AlliedSignal Technology Team include brazing to achieve final metal properties using a butt-joint configuration with long-term plans to control the integrity of the interlayer materials in the braze joint. These interlayer materials must be maintained to accommodate the differential thermal expansion between the ceramic wheel and the metallic shaft.

As with any new technology development, testing is an important step in the validation process. In this case, the air turbine starter will be tested for mechanical integrity, with in-service conditions applied in the test cell. The air turbine starter will be subjected to both a full range of normal operating conditions and emergency operation situations. Additional testing will evaluate the integrity of the system during prolonged periods of operation. Tests conducted at the Marshall Center and Lewis Research Center will investigate the nature of the cyclic fatigue with ceramic material and the ceramic-to-metal joints.

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**Biographical Sketch:** Chris Bramon is a project manager in the Technology Investment Office at NASA-MSFC. He works with industry, academia and other Government agencies to develop dual-use technologies that benefit both the public and private sectors. Bramon has an industrial engineering degree from Iowa State

University. He has worked for NASA for 12 years.

Mike Effinger is a materials engineer in the Nonmetallic Materials Division at NASA-MSFC. He conducts mechanical property testing on ceramic and ceramic matrix composites. Data generated is used for the design of rocket engine components. Effinger has worked for NASA for 5 years.

